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SPM investigations of domain walls in Barium titanate PTC thermistors

S.A.M. Tofail[1,2], M. Karimi-Jafari[1,2], A. Stapleton[1,2], Y. Guo[2], K. Kowal[1,2], D. Chovan[1,2], L. Kailas[2], A. Gandhi[1,2], K. O'Sullivan[3], A. Maher[3], E.U. Haq[1,2]

[1]*Department of Physics, University of Limerick, Limerick, V94 T9PX, Ireland*
e-mail: Tofail.Syed@ul.ie; Ehtsham.U.Haq@ul.ie

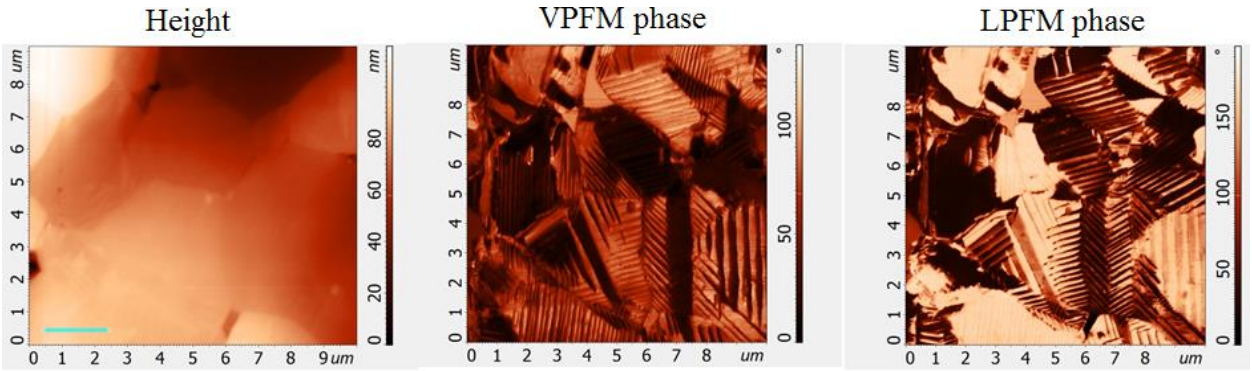
[2]*Bernal Institute, University of Limerick, Limerick, V94 T9PX, Ireland*

[3]*BorgWarner Beru Systems, Monavalley Industrial Estate, Tralee, Co. Kerry, Ireland*

Barium titanate ($BaTiO_3$) has been a very attractive material for electroceramics and microelectronics industry due to its high dielectric constant and low loss characteristics. These characteristics make it a material of choice in multilayer capacitors and energy storage devices.

Barium titanate is a ferroelectric insulator at room temperature; however, by suitable doping with ions like La^{+3}, Sm^{+3}, Ho^{+3} or Nb^{+5} the material can be tailored to become ferroelectric semiconductor at room temperature. The semiconducting property in ferroelectric $BaTiO_3$ gives rise to a huge resistivity change at the ferroelectric-paraelectric transition temperature with a positive temperature coefficient of the resistivity (PTCR) [1,2]. The PTCR effect has found numerous industrial applications like over-voltage protection, automobiles, hair-dryers and self-regulating heaters. In this study, two surface analysis tools, electron backscatter diffraction (EBSD) and piezoresponse force microscopy (PFM) were combined to investigate the crystallographic orientation, topography and intergranular polarization in polycrystalline PTC $BaTiO_3$ ceramic that leads to PTC effect.

EBSD of $BaTiO_3$ reveals individual grains of $BaTiO_3$ possess a preferred orientation. Ferroelectric domains and twinning is evident in both electron back scattered images and PFM images. In individual grains, the domains mostly appear in a single twin pair set rather than random pairs of all available phase variants. While the EBSD on these thermally etched samples showed 90° domains it could not discern the type between a-a and a-c domains. PFM, on the other hand, clearly distinguishes a-a and a-c type domains using vertical and lateral piezoresponse (Fig. 1). The work reported here will contribute to grain boundary control of PTC effect in semiconducting ferroelectric barium titanate ceramics.



(a) (b) (c)

Figure 1. (a) Atomic force microscopy topography, (b) vertical and (c) lateral piezoresponse force microscopy (phase) of barium titanate PTC thermistors.

1. J. Daniels, K. Härdtl, R. Wernicke, *Philips Technical Review* **38**, 73 (1979).
2. B. Huybrechts, K. Ishizaki, M. Takata, *Journal of Materials Science* **30**, 2463 (1995).